Republic of Iraq

Ministry of Water Resources

General Directorate for Water Resources Management

Strategy for Water and Land Resources in Iraq

Guidance Note Series

Irrigation Water Requirements

GN 03

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The guidance note describes procedures for the calculation of crop water and irrigation diversion requirements in Iraq.

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1 INTRODUCTION

1.1.1 This note presents a step by step approach to the calculation of irrigation water requirements, from the estimation of crop coefficients to the calculation of irrigation diversion requirements. The methodology adopted is that of the Food and Agriculture Organisation (FAO) given in their series of Irrigation and Drainage Papers.

- Nr 24 'Crop water requirements', reprinted 1977
- Nr 25 'Effective rainfall', 1974
- Nr 29 'Water quality for agriculture', 1976
- Nr 33 'Yield response to water', 1979
- Nr 46 'CROPWAT A computer program for irrigation planning and management', 1992
- Nr 48 'The use of saline waters for crop production', 1993
- Nr 49 'CLIMWAT for CROPWAT', 1993
- Nr 56 'Crop evapotranspiration – Guidelines for computing crop water requirements', 1998

2 REQUIREMENTS

2.1 Data Requirements

2.1.1 Before starting the calculations it is necessary to assemble the following data:

- Location of the scheme for which the calculation is to be made
  - Rainfall characteristics at that location
  - Evaporation characteristics at that location
  - Soil characteristics at that location (to estimate seepage losses)
  - Zone in which the scheme is located (refer to Map 1)
  - Water quality
- Crops to be grown, including details of the seed variety
  - First and last planting date for the chosen variety
  - Length of growing season for the chosen variety or harvest dates
  - Area to be cultivated under each crop
  - Sensitivity of yield to water quantity and quality
- Farming operations for each crop
  - Land preparation: water required and when
  - Sowing: how many plantings, how many days apart, what proportion of the area to be sown at each planting
  - Irrigation frequency
  - Constraints and/or special measures
- Irrigation system operation
  - Characteristics of the irrigation system: traditional or modern
  - Gravity supply and/or pumping
  - Estimated irrigation efficiency: field and conveyance system efficiencies.

2.1.2 Appendix A contains proforma for the collection of the necessary agronomic data from the Ministry of Agriculture.

2.1.3 Information taken from the General Scheme Stage 2 reports has been used to provide worked examples of the approach.

2.2 Software

2.2.1 For most crops the procedure involves the use of the FAO program 'CropWat' and its associated database of climate data for key stations around the world. The CropWat 4 for Windows package, its user manual, and Climwat database can be downloaded directly from the FAO web site or from Claromentis. The Near East and North Africa Climwat database contains climate data for 20 stations in Iraq.

2.2.2 However, the CropWat package does not cover all crops that may be of interest in Iraq, in particular the Windows version does not cover rice. Therefore this note explains the calculation procedure for an example crop that is included in Cropwat and for rice which is not. A workbook for calculating the requirements has been developed which, for many crops, can then be compared to the Cropwat output.

2.2.3 The workbooks are called 'Rice Diversion Requirements rev0.xls' and 'Non-rice Diversion Requirements rev0.xls'.

2.3 Climate Data

2.3.1 The most important parameters are potential evaporation (Eo) and potential evapotranspiration (ETo) from plants, and rainfall.

2.3.2 Evaporation may be measured directly using an evaporation pan, but it is usually calculated from climatic parameters by one of a number of formulae such as the 'Penman-Montieth'. The latter uses temperature, humidity, sunshine, and wind data to compute ETo.

2.3.3 The Climwat database provides a first source of climate data for Iraq. The SWLRI project has also compiled data from the Ministry of Transport.

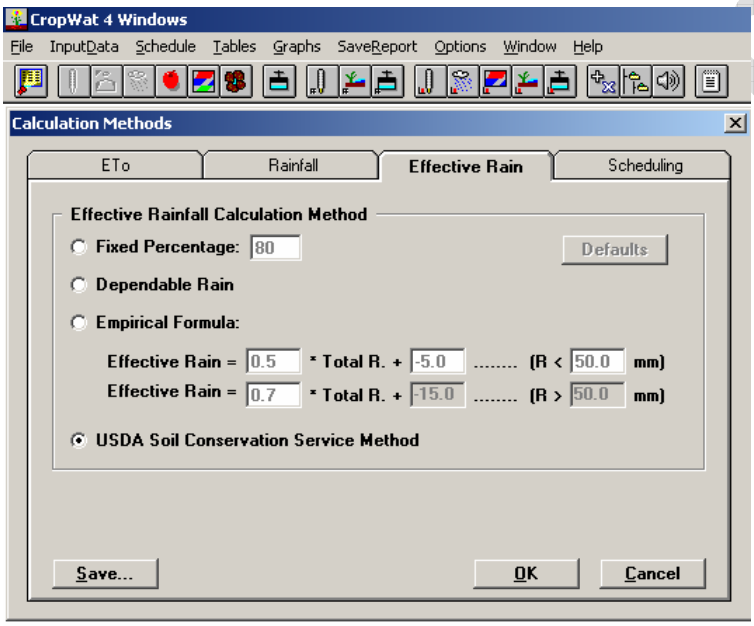
2.3.4 Either select the nearest station from the Climwat data set or from the SWLRI data set. It is better to put in data for temperature, humidity, sunshine and wind even if pan evaporation data is available so that ETo can be calculated by more than one method in CropWat.

2.3.5 Refer to the CropWat manual for instructions on how to enter and save the data for the local station, and on how to calculate evaporation and evapotranspiration.

2.3.6 Rainfall data should be entered for the nearest local station in preference to Climwat data if at all possible. Rainfall can be quite spatially variable and therefore it is better to use local data – provided that it is considered reliable.

2.3.7 Refer to the CropWat manual for instructions on how to enter and save the data for the local station, and on how to calculate the 'effective rainfall'

2.3.8 Effective rainfall is that rain that falls during the growing season and can actually be used by the crops, hence saving on irrigation applications. It is always less than the total rainfall because some rainfall runs off to streams and drains and cannot be used by the crops. The CropWat program offers more than one method for estimating effective rainfall.



2.3.9 It is recommended that the USDA Soil conservation method is used with CropWat (the default) for manual calculation a fixed percentage may be more appropriate.

2.4 Crop Coefficients

2.4.1 Evapotranspiration losses from a field are the sum of crop transpiration (ETcrop) and evaporation from the soil surface. ETcrop is derived from ETo (potential evapotranspiration) using crop coefficients (kc).

2.4.2 The crop growing season of field and vegetable crops has been divided into four stages (FAO Paper 24). Crop coefficients (kc) for given stages of crop development and different climatic conditions are presented in Tables 1 and 2 of that publication; they are also available through the Cropwat software. The need to collect local data on growing season length and rate of crop development is highlighted.

2.4.3 The four stages in crop development are defined below.

1. Initial stage – germination and early growth when the soil surface is not, or is hardly covered by the crop (groundcover <10%)

2. Crop development stage – from the end of the initial stage to attainment of effective full groundcover. Start of the mid-season stage can be recognised in the field when the crop has attained 70-80% groundcover which, however, does not mean that the crop has reached its mature height. Effective full groundcover refers to cover when kc is approaching a maximum.

3. Mid-season stage – from attainment of effective full groundcover to time of start of maturing as indicted by discolouring of leaves (beans) or leaves falling off (cotton). For some crops this may extend to very near harvest (sugarbeets) unless irrigation is not applied at late season and a reduction in ETcrop is induced to increase yield and/or quality (sugarcane, cotton, some grains); normally well past the flowering stage of annual crops.

4. Late season stage – from end of mid-season stage until full maturing or harvest.

2.4.4 In FAO Paper 33 a more detailed description is provided of the growth stages of major crops, highlighting periods when full water supply is critical to high yields.

2.4.5 The steps needed to arrive at the kc values for the different growth stages are illustrated by an example of a maize crop to the grown on the Lower Khalis project as a summer season crop. The following extract from FAO Paper 33 gives the range of kc values for maize.

2.4.6 ‘Maize is an efficient user of water in terms of total dry matter production and among cereals it is potentially the highest yielding grain crop. For maximum production a medium maturity grain crop requires between 500 and 800 mm of water depending on climate. To this, water losses during conveyance and application must be added. The crop factor (kc) relating water requirements to reference evapotranspiration is: initial stage 0.3 – 0.5 (15 to 20 days), the development stage 0.7 – 0.85 (30 to 45 days), the mid-season stage 1.05 – 1.2 (30 to 45 days), during the late season stage 0.8 – 0.9 (10 to 30 days), and harvest 0.55 – 0.6.’

Figure 2.1: Maize development stages

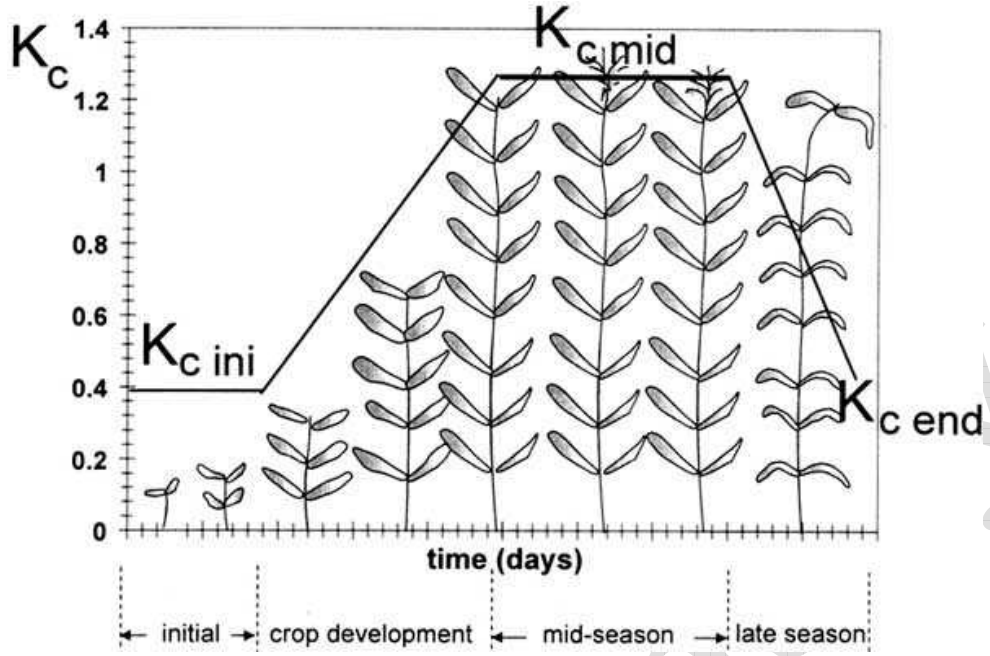
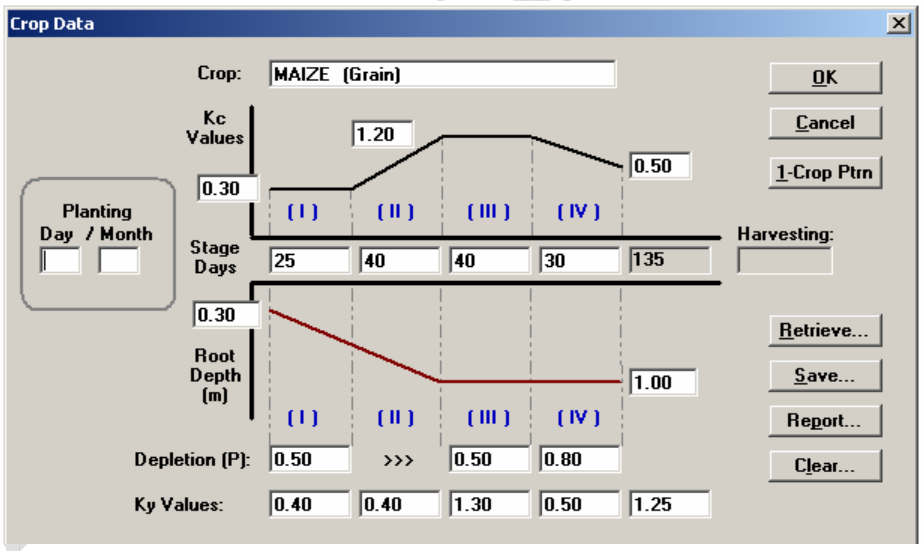


Figure 2.2: Maize crop data entry screen in CropWat



2.4.7 Where local information on the proposed crop variety does not match that provided as the standard in CropWat it is possible to edit the file and put in more appropriate lengths for each of the stages.

2.4.8 For maize on the Lower Khalis project:

1. Establish the planting date

2. Determine the total growing season and the length of each growth stage from local information

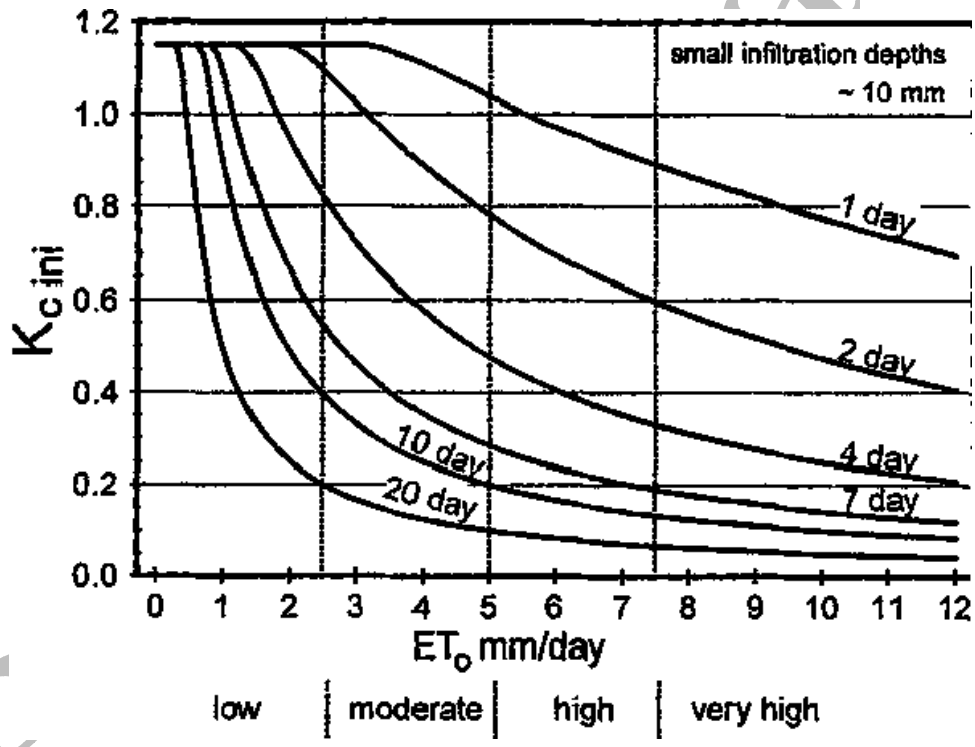
3. Initial stage: predict irrigation and/or rainfall frequency for predetermined ETo value select the initial kc value from the graph (Figure 2.3) below

4. Mid-season stage and late-season stage: for given climate (humidity and wind) select kc values from FAO publication tables

5. Join up the coefficients as shown in Figure 2.1 and Figure 2.2 above.

6. For each period being analysed (e.g. 15 day) obtain the kc value from the graph that you have drawn up.

Figure 2.3: Prediction of irrigation and/or rainfall frequency



3 IRRIGATION DIVERSION REQUIREMENTS

3.1 Introduction

3.1.1 Usually requirements are calculated for a series of planting dates to enable optimum planting dates to be selected. To reduce the peak water requirement and to spread the labour inputs it is usual to adopt staggered planting in three steps. The time interval selected will depend on the likely pattern of crop irrigations, 10 or 15 day intervals may be selected.

3.1.2 The calculation procedures for field crops and paddy rice crops are slightly different and hence are discussed separately, field crops first.

3.2 Field Crops

3.2.1 The calculations for field crops can be carried out within CropWat. The user manual gives detailed instructions. Here the method is summarised to demonstrate the main principles and to allow a comparison with the calculations for rice crops.

Land Preparation

3.2.2 The amount of water and period for land preparation must be determined from local information. Water may be required to leach accumulated salts from the soil or just as an aid to tillage depending on local conditions.

Consumptive Use

3.2.3 Actual evapotranspiration is calculated from the potential ETo and the kc value for each period

Percolation and Seepage

3.2.4 These rates depend on the soil type and the location of the groundwater table. The results of infiltration tests carried out in the study area in actual fields should be used where possible. It is usual to use standard figures and account for local factors through the field efficiency factor.

Effective Rainfall

3.2.5 Described in Section 2.3.7 above.

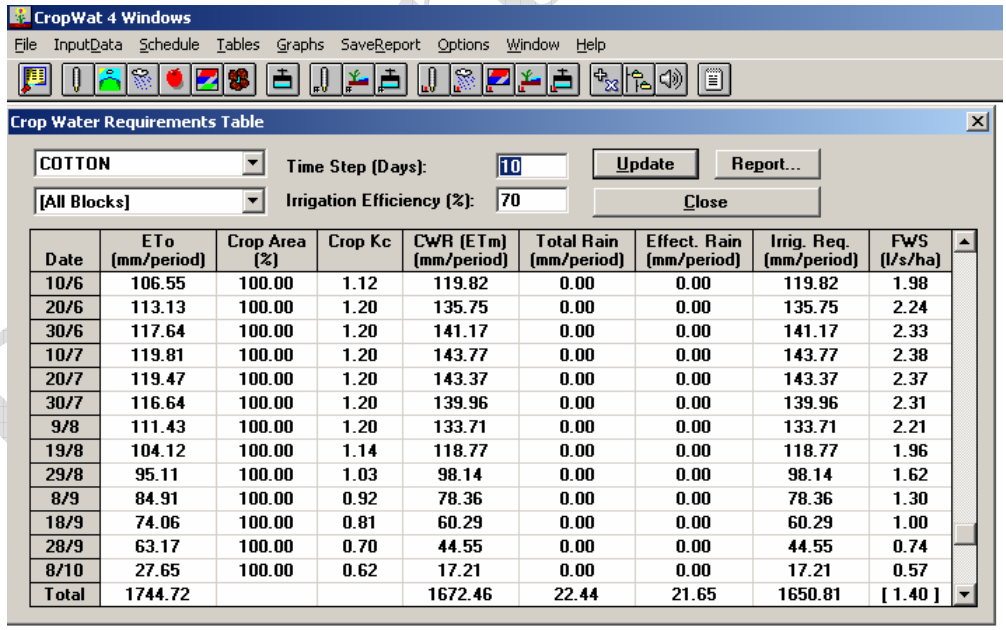
Irrigation Efficiency

3.2.6 Field losses can become large when applying relatively small amounts of water to dry-foot crops. Local information should be used where available. The General Scheme suggests farm plot values of between 0.7-0.75, and farm canal factors of around 0.9-0.95.

3.2.7 Further in order to allow for water losses from the canal system, from seepage, evaporation, gate leakage, etc an irrigation efficiency is estimated for the main canal and for secondary and tertiary canals. The efficiency factor should if possible be based on local information.

3.2.8 The factors are multiplied up so that farm plot and canal efficiencies together are 0.7*0.9 or 0.63. This factor is then multiplied by the canal system efficiency factor.

Figure 3.4: Calculation of Cotton Water Requirements in CropWat



Date	ETo (mm/period)	Crop Area (%)	Crop Kc	CWR (ETm) (mm/period)	Total Rain (mm/period)	Effect. Rain (mm/period)	Irrig. Req. (mm/period)	FWS (l/s/ha)
10/6	106.55	100.00	1.12	119.82	0.00	0.00	119.82	1.98
20/6	113.13	100.00	1.20	135.75	0.00	0.00	135.75	2.24
30/6	117.64	100.00	1.20	141.17	0.00	0.00	141.17	2.33
10/7	119.81	100.00	1.20	143.77	0.00	0.00	143.77	2.38
20/7	119.47	100.00	1.20	143.37	0.00	0.00	143.37	2.37
30/7	116.64	100.00	1.20	139.96	0.00	0.00	139.96	2.31
9/8	111.43	100.00	1.20	133.71	0.00	0.00	133.71	2.21
19/8	104.12	100.00	1.14	118.77	0.00	0.00	118.77	1.96
29/8	95.11	100.00	1.03	98.14	0.00	0.00	98.14	1.62
8/9	84.91	100.00	0.92	78.36	0.00	0.00	78.36	1.30
18/9	74.06	100.00	0.81	60.29	0.00	0.00	60.29	1.00
28/9	63.17	100.00	0.70	44.55	0.00	0.00	44.55	0.74
8/10	27.65	100.00	0.62	17.21	0.00	0.00	17.21	0.57
Total	1744.72			1672.46	22.44	21.65	1650.81	[1.40]

3.3 Rice Crops

Land Preparation and Nursery

3.3.1 A period for land preparation must be determined from local information. The nursery requirement is normally for 20-25 days. The period allowed for land preparation usually includes the nursery period.

3.3.2 The major water requirement at the start of the land preparation is to saturate the soil and establish a water layer, whereas towards the end of the period topping up to overcome evaporation and seepage losses is the predominant requirement.

Consumptive Use

3.3.3 Actual evapotranspiration is calculated from the potential ETo and the kc value for each period

Percolation and Seepage

3.3.4 Such seepage losses as occur are normally reused in adjacent fields so no special allowance for seepage needs to be made.

3.3.5 The results of infiltration tests carried out in the study area in actual wet paddy fields should be used where possible. In general infiltration rates on land classified as suitable for rice are 1-4 mm/day

Effective Rainfall

3.3.6 Described in Section 2.3.7 above

Water layer replacement

3.3.7 In order to apply fertiliser and carry out weeding operations it is usual to draw down the water level in the paddy fields. The water layer must then be replaced. The amount and timing for water layer replacement application(s) should be based on local practices.

Irrigation Efficiency

3.3.8 In order to allow for water losses from the canal system, from seepage, evaporation, gate leakage, etc an irrigation efficiency is estimated for the main canal and for secondary and tertiary canals. The efficiency factor should if possible be based on local information.

3.4 Total Irrigation Demand

3.4.1 The total monthly (or other interval) demand at the head of the system depends on the selected cropping pattern and cropping intensity. Unit diversion requirements for the crops involved are multiplied by the proposed area and summed to give the total demand in million cubic metres for comparison with river flows or reservoir releases.

3.4.2 It should be noted that this is the theoretical demand for supply to the crop from the head of the system and does not take account of operational water requirements for other purposes that are met from the irrigation network – in Iraq the flow in irrigation canals may be determined by the needs for downstream users (environment, local water supply), to maintain levels, or to pass flood waters.

3.4.3 Sample output from the Non-rice Diversion Requirements.xls and Rice Diversion Requirements.xls workbooks follows.

Crop Water and Diversion Requirements for: **Maize (grain), variety ?, Iraq, Central Zone**

Period (0.5 month)	Crop Coefficient	Evapotrans-piration mm/d	Land Preparation mm/d	Consumptive Use mm/d	Percolation mm/d	Water Layer Replacement mm/d	Total mm/d	Effective Rain mm/d	Net Water Requirement mm/d	Crop Water Requirement l/s/ha	Field Requirement l/s/ha	Diversion Requirement l/s/ha
February 1	0.00	2.5	2.00	0.00	0		2.00	0.80	1.20	0.14	0.20	0.31
February 2	0.00	2.5	2.00	0.00	0		2.00	0.80	1.20	0.14	0.20	0.31
March 1	0.58	3.9		2.28	0		2.28	0.86	1.42	0.16	0.23	0.36
March 2	0.58	3.9		2.28	0		2.28	0.86	1.42	0.16	0.23	0.36
April 1	0.82	5.4		4.40	0		4.40	0.71	3.69	0.43	0.61	0.94
April 2	0.82	5.4		4.40	0		4.40	0.71	3.69	0.43	0.61	0.94
May 1	1.08	7.5		8.13	0		8.13	0.26	7.87	0.91	1.30	2.00
May 2	1.08	7.5		8.13	0	0.67	8.80	0.26	8.53	0.99	1.41	2.17
June 1	0.80	10.8		8.62	0	0.67	9.29	0.00	9.29	1.07	1.54	2.36
June 2	0.80	10.8		8.62	0		8.62	0.00	8.62	1.00	1.43	2.19
July 1	0.00	11.8		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
July 2	0.00	11.8		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
August 1	0.00	11.1		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
August 2	0.00	11.1		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
September 1	0.00	7.9		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
September 2	0.00	7.9		0.00	0		0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	5.0		0.00	0		0.00	0.10	0.00	0.00	0.00	0.00
October 2	0.00	5.0		0.00	0		0.00	0.10	0.00	0.00	0.00	0.00
Total (mm)				703			783	82	704		1006	1547
Peak requirement (l/s/ha)												2.36

Factors and allowances	
LP (mm)	60
Nr of periods for LP	2
WLR (mm)	20
Nr of periods for WLR	2
Field Efficiency	70%
Conveyance Efficiency	65%
Percolation (mm/d)	0
Growing season (days)	120
Calculation period (days)	15

Notes:

Zones as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Crop coefficients for this crop in this zone as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Evapotranspiration rates as given in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Effective rainfall as given in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982?

Field efficiency as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Conveyance efficiency (canal system) as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Land preparation requirement as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Water layer replacement as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982?

Percolation rates from ? Assuming soil type ?

Crop Water and Diversion Requirements for: **Paddy rice, variety Basian, Iraq, Central Zone**

Period (0.5 month)	Crop Coefficient	Evapotrans-piration mm/d	Land Preparation mm/d	Consumptive Use mm/d	Percolation mm/d	Water Layer Replacement mm/d	Total mm/d	Effective Rain mm/d	Net Water Requirement mm/d	Crop Water Requirement l/s/ha	Field Requirement l/s/ha	Diversion Requirement l/s/ha
April 1	0.00	5.4	8.33	0.00	4		12.33	0.71	11.63	1.35	1.35	2.07
April 2	0.00	5.4	8.33	0.00	4		12.33	0.71	11.63	1.35	1.35	2.07
May 1	1.10	7.5		8.28	4	2.67	14.95	0.26	14.68	1.70	1.70	2.61
May 2	1.10	7.5		8.28	4	2.67	14.95	0.26	14.68	1.70	1.70	2.61
June 1	1.20	10.8		12.92	4	2.67	19.59	0.00	19.59	2.27	2.27	3.49
June 2	1.20	10.8		12.92	4	2.67	19.59	0.00	19.59	2.27	2.27	3.49
July 1	1.25	11.8		14.79	4	2.67	21.46	0.00	21.46	2.48	2.48	3.82
July 2	1.25	11.8		14.79	4	2.67	21.46	0.00	21.46	2.48	2.48	3.82
August 1	1.05	11.1		11.69	4	2.67	18.36	0.00	18.36	2.12	2.12	3.27
August 2	1.05	11.1		11.69	4	2.67	18.36	0.00	18.36	2.12	2.12	3.27
September 1	0.65	7.9		5.12	4		9.12	0.00	9.12	1.06	1.06	1.62
September 2	0.00	7.9		0.00	4		0.00	0.00	0.00	0.00	0.00	0.00
October 1	0.00	5.0		0.00	4		0.00	0.10	0.00	0.00	0.00	0.00
October 2	0.00	5.0		0.00	4		0.00	0.10	0.00	0.00	0.00	0.00
Total (mm)				1507			2737	32	2708		2708	4166
Peak requirement (l/s/ha)												3.82

Factors and allowances	
LP (mm)	250
Nr of periods for LP	2
WLR (mm)	320
Nr of periods for WLR	8
Field Efficiency	100%
Conveyance Efficiency	65%
Percolation (mm/d)	4
Growing season (days)	120
Calculation period (days)	15

Notes:

Zones as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Crop coefficients for this crop in this zone as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Evapotranspiration rates as given in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Effective rainfall as given in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982?

Field efficiency as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Conveyance efficiency (canal system) as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Land preparation requirement as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982

Water layer replacement as defined in the Russian 'General Scheme for Water and Land Resources in Iraq', 1982?

Percolation rates from ? Assuming soil type ?

4 YIELD RESPONSE TO WATER

4.1 Yield Response to Water Quantity

4.2 Yield Response to Water Quality

Appendix A Data Compilation Proforma

1. Crop data: variety, planting dates, harvest dates, operations and their timing
2. Overall cropping calendar
3. Local climate data